



Project Summary

Products of Incomplete Combustion from Direct Burning Of Pentachlorophenol-treated Wood Wastes

S.Y. Lee and J.C. Valenti

The report gives results of a study to identify potential air pollution problems from the combustion of waste wood treated with pentachlorophenol preservative for energy production in a boiler. The study emphasized the characterization of the products of incomplete combustion (PICs) in the combustion flue gas. The methodology used was to compare the flue gas concentrations of PICs prior to the air pollution control device of a pilot-scale combustor burning untreated wood and burning wood treated with pentachlorophenol preservative. The tests showed that combustion is an effective method of destroying the pentachlorophenol in the treated wood, with destruction efficiencies higher than 99.99%. Differences in the flue gas concentrations of various PICs from the combustion of untreated and treated wood fuels have been noted. The data do not enable identification of the exact cause of these differences in flue gas concentrations. These differences are possibly caused by the significantly different chlorine content of the two fuels. The difference in flue gas flow rate required for the combustion of these two fuels with different combustion characteristics (moisture content and heating value) may also cause the differences in PIC formation rates. These data are strongly influenced by the design, configuration, and operation of the combustor system and may not be quantitatively

comparable to other combustors.

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Introduction

The use of waste wood as fuel for producing energy is a promising supplement to fossil fuels for many regions of the country. In addition to recovering energy and conserving landfill space, burning waste wood fuels also mitigates global warming by replacing fossil fuel use. However, the environmental consequences resulting from emissions generated by combustion of waste wood which contains paints, resins, or preservatives are not well understood. Combustion of these materials could produce potentially hazardous products of incomplete combustion (PIC) emissions such as dioxins and furans.

Characterization of PICs from the combustion of waste wood treated with pentachlorophenol is reported in this study. Utility poles and crossbars are typically treated with a preservative such as pentachlorophenol in order to prolong their service life. They are disposed of by land filling after being taken out of service. Burning such wood waste in boilers for steam generation becomes an increasingly

attractive waste management alternative as it contains substantial energy values and reduces land filling costs. Pilot-scale combustion tests were conducted under well controlled conditions in a 0.58 MW (2 million Btu/hr) combustor to characterize PICs from burning pentachlorophenol-treated wood. The methodology used was a side-by-side characterization of flue gases from burning treated wood and similar untreated wood. The gases were sampled prior to the combustor's air pollution control equipment to avoid the effects of the control equipment. Sampling and analyses for a wide variety of PICs, including volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), dioxins, and furans, were performed to assess the effect of pentachlorophenol preservative present in wood on PIC emissions.

Experimental

The combustion testing was conducted using a multifuel combustor (MFC) installed in the Environmental Protection Agency's research facility located at Research Triangle Park, North Carolina. The MFC is a pilot-scale stoker combustion system with 0.58 MW (2 million Btu/hr) maximum thermal output which is sufficient for simulating the full range of conditions that are typically encountered in operating combustors. The MFC facility contains a fuel storage and feed system, a stoker combustor section, radiant heating sections, convective heating sections, a fabric filter baghouse, and a caustic wet scrubber. The MFC is capable of burning a wide variety of solid fuels including municipal solid waste, refuse derived fuel, biomass fuel, and coal singly or in combination. The combustor is constructed with modular sections, which provides maximum flexibility for modifying the combustor for research purposes. Access ports are installed throughout the entire combustor for sampling and visual observation. The combustor was operated in a spreader stoker firing mode during the test period.

Two different wood fuels, untreated wood and treated wood, were obtained from a plant where wood poles are treated with pentachlorophenol. The untreated wood was pine poles that are typically treated in the plant. The treated wood was a mixture of recently treated poles, mostly small pieces cut from the ends to meet customers' length specifications, and aged treated poles taken out of service. Both

treated and untreated poles were ground into chips less than 7.6 cm (3 in.) in diameter. The two fuels were characterized by proximate, ultimate, and chlorine analyses. The treated wood fuel is drier with higher heating value, compared to the untreated wood. The chlorine content of the treated wood fuel is 10 times higher than that of the untreated wood.

The only parameter investigated was the difference in emissions when burning treated vs. untreated wood fuels under similar combustion conditions; no attempt was made to conduct parametric tests for this study. In general, the operating conditions of the test were considered optimal when the fuel was burning at the designed heat release rate with nominally 160% excess air and a low level (< 100 ppm) of carbon monoxide (CO) emissions in the flue gas.

The amount of fuel burned was not measured continuously during a test. It was estimated by weighing the fuel before it was dumped into the loading hopper of the MFC and measuring the time required for its complete consumption to calculate an average feed rate. The average feed rate was used to estimate the amount of fuel burned during a timed emissions sampling period. The MFC is equipped with continuous emission monitors (CEMs) -- for measuring oxygen (O_2), CO, carbon dioxide (CO_2), nitrogen oxide (NO), sulfur dioxide (SO_2), total hydrocarbon (THC), and hydrogen chloride (HCl) -- and equipment for continuously monitoring process temperatures and pressures.

The emissions sampling point was at the duct which connects the convective section of the furnace to the baghouse. The selection of a sampling point prior to any gas cleaning device was made to ensure that any difference in flue gas pollutant concentrations generated by combustion of treated and untreated wood fuels would be observed. Emission measurements made after the flue gas cleaning device would be expected to mask this difference and would reflect the effectiveness of the devices (i.e., baghouse and caustic scrubber) used.

The sampling and analysis program focused primarily on organic emissions, particularly those which are considered potentially hazardous, from the combustion of wood fuels. Sampling and analytical protocols used were based on existing EPA methods for measuring organic constituents in flue gases.

Results and Discussion

Six combustion tests, three each for both the untreated and the treated wood fuels, were performed under similar combustor operating conditions. The untreated wood tests were performed first, followed by the treated wood tests to avoid cross contamination. Triplicate runs were made to determine experimental repeatability. Since it was not practical to measure fuel feed rate continuously, the tests were performed under constant excess air level (nominally 160% excess air) and a constant combustion gas temperature (850°C) measured by a thermocouple located 152 cm (60 in.) above the grate. The heat release rate was set at 80% of the maximum designed output of the MFC. The fuel feed rate was adjusted manually throughout all tests to maintain a constant temperature of 850°C above the stoker grate and keep CO emissions below 100 ppm, which were considered optimum conditions for the tests.

It was difficult to produce identical combustion conditions for all the tests, mainly because the two wood fuels are not homogeneous. The treated wood fuel contains aged wood, which is drier, and has 30% higher heating value than the untreated wood fuel. Uneven fuel feed rates resulting from the fairly frequent manual adjustment of the fuel feeder could have caused fluctuations in air-to-fuel ratio and momentary excursions of CO emissions, especially when burning untreated wood. CEM data for CO and CO_2 and visual observations of fuel flow into the stoker suggest that small excursions occurred during the tests. The nonhomogeneous nature of the fuels, coupled with the practical difficulties to burn such fuels under well defined conditions, made the accurate estimation of heat release rates difficult. The measured combustion gas temperature also may not have been always truly representative of average temperature across the combustor in a given axial position due to a non-uniform gas temperature profile. Tremendous gas flow turbulence was generated above the burning hot fuel bed when the cold underfire air passed through the grate and the cold overfire air was injected into the furnace above the grate. Observations through viewing ports indicated turbulent

flow along the entire convective section during the tests.

Pentachlorophenol Destruction Efficiency

The concentration of pentachlorophenol in the treated wood fuel averaged 4,100 mg/kg (ppmw). No pentachlorophenol was detected in any of the SVOC samples collected during the six tests. The estimated pentachlorophenol destruction efficiency (DRE) for each test has been conservatively calculated based on the pentachlorophenol analysis practical quantitation limit (PQL). The PQL is based on the lowest calibration concentration and does not include factors such as percent recovery or matrix effects. Burning of the pentachlorophenol-treated waste wood in a stoker combustor destroys the pentachlorophenol efficiently with a DRE higher than that required for hazardous waste destruction (99.99%).

VOC Emissions

Analyses were performed for 50 VOCs in each test sample. Only eight compounds were found in concentrations higher than the analytical detection limit in at least one test. Higher levels of benzene were found in the untreated wood test samples, while bromomethane was found at higher levels in the treated wood test samples. Chloromethane, 1,3-butadiene, iodomethane, acetone, chloroform, and 1,2-dichloroethane were found in both untreated and treated wood test samples. The trace levels of chlorinated VOC emissions found in the untreated wood tests may possibly be caused by small amounts of naturally occurring chlorine in untreated woods. Higher concentrations of chlorinated VOCs were typically found in the treated wood tests, probably as a result of higher chlorine content in the treated wood.

SVOC Emissions

Of the 87 SVOCs for which analyses were performed in the SVOC samples, only five targeted compounds were found above the analytical detection limits: phenol, acetophenone, naphthalene, 2-nitrophenol, and phenanthrene. The typically low SVOC emissions for both the untreated and treated wood tests indicate that good combustion conditions were achieved during the tests. The slightly lower SVOC concentrations for the treated wood tests compared to those for the

untreated wood tests also suggest that the combustion of the drier treated wood fuel produced lower PICs. More moisture released during the combustion of the "green" untreated wood fuel may lower the localized combustion zone temperature and cause more PIC formation.

Dioxin/Furan Emissions

Total polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran (PCDD/PCDF) concentrations [using the International Toxic Equivalency (I-TEQ) method of accounting for different toxicities of PCDD/PCDF congeners] averaged 0.274 and 1.190 ng I-TEQ/dscm from the untreated and treated wood tests, respectively. These flue gas concentrations are prior to any control devices. Particulate control devices could potentially remove part of this material from the gas stream, depending on the fly ash collection efficiency, PCDD/PCDF formation, and solid-to-vapor-phase partition with the device. The temperature of the flue gas at the sampling point was between 150 and 160°C. It has been shown that the dioxin and furan formation "temperature window" in flue gases is between 200 and 450°C. It is reasonable to expect that the formation of dioxin and furan in the flue gas has already been completed before the sampling location. It is also likely that the rates of formation and desorption of fly-ash-associated PCDD/PCDF in a subsequent particulate collection device would be low at temperatures below 160°C. The PCDF concentrations are significantly greater than PCDD concentrations for both the untreated and treated wood tests, indicating *de novo* synthesis formation reactions rather than condensation reactions. The PCDD/PCDF congener distributions for the treated and untreated tests also differ. In the untreated wood tests, distribution is peaked at the lower-chlorinated tetra-PCDD and di-PCDF congeners; in the treated wood tests, distribution is shifted to the higher-chlorinated hexa-PCDD and penta-PCDF congeners. The PCDD/PCDF concentrations measured from both the untreated and treated wood tests are considered low when compared to the stack concentrations from commercial municipal waste combustors, which range from 0.01 to 400 ng I-TEQ/dscm. The low PCDD/PCDF concentrations measured from the untreated wood tests are similar to those from burning natural wood, which range from 0.066 to 0.214 ng I-TEQ/dscm.

The PCDD/PCDF concentrations from the treated wood tests are higher than those reported (0.0359 ng I-TEQ/dscm) from a waste-to-energy plant burning a mixture of clean wood and pentachlorophenol-treated waste wood.

The higher PCDD/PCDF concentrations from the treated wood tests compared to those from the untreated wood tests are consistent with their higher HCl and chlorinated VOC concentrations. Approximately 200 ppm of HCl was measured in concentrations from the treated wood tests, while HCl was not detected in the untreated wood tests. By weighing and analyzing the front and back halves of the PCDD/PCDF sampling train separately, an indication of the PCDD/PCDF associated with the particulate material and as gaseous concentrations was observed. The percentage of PCDD/PCDF in the front half catch is greater in the treated wood tests than in the untreated wood tests. The treated wood tests had a higher flue gas flow rate as a result of the higher heating value of the treated wood burned, which would enhance particulate load at the sampling point. This information suggests that particulate carryover from the combustor may affect the total amount of PCDD/PCDF, especially in the treated wood samples where a larger percentage is in the front half catch. Combustor operating conditions in addition to the wood treatment may also contribute to higher measured PCDD/PCDF concentrations for the treated wood tests.

Conclusions

This study was conducted to identify potential air pollution problems associated with the combustion of utility poles treated with pentachlorophenol preservative for energy production in a boiler. The study emphasized the characterization of the PICs in the combustion flue gas. The methodology used was to compare the flue gas concentrations of PICs prior to the air pollution control device of a pilot-scale combustor burning untreated wood and wood treated with pentachlorophenol preservative as a fuel. The tests showed that combustion is an effective method of destroying the pentachlorophenol

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differences in flue gas concentrations. These differences are possibly caused by the significantly different moisture content, heating value, and chlorine content of the two fuels. The difference in flue gas flow rate required for the combustion of these two fuels with different combustion characteristics (moisture content and

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The complete report, entitled "Products of Incomplete Combustion from Direct Burning of Pentachlorophenol-Treated Wood Wastes," (Order No. PB98-127731: Cost: \$35.00, subject to change) will be available only from:

National Technical Information Service

5285 Port Royal Road

Springfield, VA 22161

Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

National Risk Management Research Laboratory

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711



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